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New Fully Automatic Fast Registration Method for 2D Computed Tomography Images

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Abstract: This research proposes and implements a new fully automatic fast registration method for 2D Computed Tomography images. In this proposed method, the images are smoothened and edges are detected using Laplacian of Gaussian filter. Fast Fourier transform is applied to the source and reference images to split the phase and magnitude. The registered image is reconstructed using Inverse Fourier Transform. The proposed method is found to have salient features namely, less human interaction, significant reduction in computational speed and provides very precise image registration with sub-pixel accuracy when compared with the traditional approaches.

Key words: Registration, mono-modal, correlation, transformation, computed tomography

INTRODUCTION

This research work proposes and implements a new fully automatic fast registration method for 2D Computed Tomography (CT) images.

The mathematical background of the new proposed method gives the following expected enormous strengths in the technique, namely

- Fully automatic
- Less human interaction
- Significant reduction in computational speed
- Accurate image registration results, compared with the traditional approaches.

This study introduces the new proposed methodology and also discusses the successful experimentation, followed by discussion of results which establish the strengths mentioned above.

MEDICAL BACKGROUND

Medical images are widely used in health care and bio-medical research. Commonly used medical imaging techniques show different aspects of anatomy examination. Registration is one of those techniques, which is of paramount importance in a number of image processing tasks. Image registration is a process of aligning the images in order to relate the corresponding features (Maintz and Viergever, 1998; Thévenaz *et al*., 1998).

It is necessary for

- Correcting the changes in images taken at different times or under different conditions
- Surgical planning like tumor removal
- 3D reconstruction.

Even though lots of methods have been developed for registration, existing techniques either requires lot of interaction or were prohibitively slow.

This study gives a fast algorithm for image registration using Phase Correlation and Affine Transformation, which is intended for use by beginners as well as by advanced users. Phase Correlation is an elegant method to align the images, which are shifted relative to one another. To register two images a transformation must be found so that each point in one image can be mapped to a point in the other. Affine transformation is used to match two images of a scene taken from the same viewing angle but from a different position.

STUDY OF PREVIOUS METHODS

Several methods are available for rigid and no rigid registration. Some of them are

Curve method: searches the corresponding open curves manually and were matched by searching for the optimal fit of the local curvatures in the two curves.

Surface method: Registration was accomplished by first identifying surfaces of similar anatomic structures in each

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image set. A transformation that best registered these structures was determined using a nonlinear optimization procedure .

Moment and principal axes methods: Moments are used to characterize the rigid bodies by the spatial distribution of their mass. Principal axes are those orthogonal axes about which the moments of the inertia are minimized. If two objects are identical except for the translation and rotation, then they can be registered by bringing the principle axes to coincidence.

Correlation method: A parameterized geometrical transformation to be applied to one of the images is selected to correct for variation in acquisition conditions.

Atlas method: The atlas volumes are first transformed with an affine mapping. The transformation is specified on the basis of point-landmarks followed by matching of surfaces or atlas counters on the images.

Wavelet-based method: Wavelet based image registration can be performed in two ways

- Selecting wavelet coefficients by selection rules in the multi-spectral image and the high resolution image for each band
- Replacing partial wavelet coefficients of the high-resolution image with these of the multi-spectral low-resolution of the image.

Mutual information based method: For two images, the mutual information is computed from the joint probability distribution of the image's intensity or gray-values. When two images are aligned, the joint probability distribution is peaky resulting in a high mutual information value.

Out of these methods Correlation methods are useful primarily for Monomodality image registration, particularly comparison of serial images of the same object.

NEW PROPOSED REGISTRATION METHOD

The following paragraphs discuss the new proposed registration method, which has a lot of inherent mathematical strengths. The discussion gives a detailed idea of the new proposed registration method.

Preprocessing: Usually, raw images are noisy. The noise makes it difficult to find the truly best transformation. So some local image pre-processing method should be used to suppress noise or other small fluctuations in the image. Smoothening and Edge detection are the preprocessing tasks performed before the registration.

Smoothening use a small neighbourhood of a pixel in an input image to get a new brightness value in the output image which also referred to as filteration. Gaussian filter is the smoothing method used in our approach, which is more sophisticated than average approach.

Convoluting the image with the Gaussian filter reduces noise (Giedke and Ignacio Cirac, 2002). If a noisy pixel is picked out it can be restored as an average value of neighboring pixel.

Edges are places in the image with strong intensity contrast and are detected by using Laplacian method which uses the zero crossing of second derivative (Gonzalez and Woods, 2002). Since edges often occur at image locations representing object boundaries, edge detection is extensively used in image registration and segmentation.

Even though smoothening is applied to reduce the noise the non-maxima suppressed image contains some false edge fragments. Apply the threshold and set the values below the threshold to zero removes the false edge fragments and increases the edge strength.

Fourier method: Fourier method, in common used to convert the spatial domain into frequency domain is applied here to split the image into phase and magnitude (Wakin *et al*., 2003). In image processing, often only the magnitude of the Fourier Transform is displayed as it contains most of the information of the geometric structure of the spatial domain image. In order to re-transform the Fourier image into correct spatial domain both phase and magnitude has been preserved.

Implementing Fast Fourier transformation of the function of interest, the magnitude for the different Fourier harmonics are obtained (Brigham and Oren, 1988; Bracewell, 1965; Stone, 2002).

If the sine and cosine function of the first harmonic fits the data on a pixel-by-pixel basis, respective magnitudes can be obtained. From this sine or cosine function a shift is computed which results in phase.

In CT imaging the phase image is a pixel-by-pixel representation of phase angle formed between XY planes.

Phase correlation: Phase correlation relies to the translation property of the Fourier transform (Kuglin and Hines, 1975; Foroosh *et al*., 2002).

The idea behind this method is quite simple, which states that a shift in the coordinate frames of two functions is transformed in the Fourier domain as linear phase differences. The two images I1 (X, Y) and I2(X, Y) having the same Fourier magnitude but phase difference related to their displacement (dx, dy) is given by

$$I2\ (x, y) = I1\ (x\text{-}dx, y\text{-}dy)$$

Their corresponding Fourier Transforms are given by

$$I2\ (x, y) = \exp\ (\text{-}I\ (xdx + ydy)^*\ I1\ (x, y))$$

The phase correlation contains a single coherent peak at the point of registration. The magnitude of the coherent peak is the measure of degree of congruence between the images. The power in the coherent peak corresponds to the percentage of overlapping areas whereas the power in the incoherent peak corresponds to the percentage of non-overlapping areas.

Features of an image are extracted during phase correlation based on the edge strength of the image. Phase value of source and reference images are compared and the number of corresponding features between the pair of images to be registered are extracted in order to estimate the transformation.

The set of feature of one image is then translated, rotated and scaled which will be proceeded by affine transformation so as to minimize some similarity function with respect to the features from the other image. Some of the common features are corresponding points, edges and contours etc (Xiao *et al*., 2005).

Affine transformation: From the coordinates of corresponding points extracted during phase correlation a transformation function has to be determined. The detected images are subject to geometric distortion introduced by perspective irregularities when the position of the camera(s) with respect to the scene alters the apparent dimensions of the scene geometry.

Applying an affine transformation to an uniformly distorted image can correct for a range of perspective distortions by transforming the measurements from the ideal coordinates to those actually used.

The affine transformation is composed of a scaling, a translation and a rotation (Reddy and Chatterji, 1996). It is a global transformation since the overall geometric relationships between points do not change. It has four parameters tx, ty, s, θ which maps the point I1(x_1, y_1) of the first image with point I2 (x_2,y_2) of the second image can be given by

$$\begin{pmatrix} x_2 \\ y_2 \end{pmatrix} = \begin{pmatrix} t_x \\ t_y \end{pmatrix} + S^* \begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} x_1 \\ y_1 \end{pmatrix}$$

Image reconstruction: The magnitude only image unrecognizable and has severe dynamic range problems. The phase-only image is rarely recognizable, that is, severely degraded in quality therefore both the phase and magnitude is necessary for the complete reconstruction of an image. This can be done by applying the inverse Fourier transform.

EXPERIMENTAL RESULTS

Experiments are done on the new proposed fully automatic fast registration method for 2D Computed Tomography (CT) images. The results indicate accomplishment of successful fully automatic fast registration. The following paragraphs give a detailed understanding of the experimental results and the strengths of the new fully automatic fast registration method.

The proposed registration method is applied to a set of 2D CT images which are 8-bit gray scale images with intensity values scaled into the range (0, 1) in order to test the efficacy. The process starts by computing the magnitude and phase of the image as previously discussed.

The new proposed fully automatic fast registration methods is observed to have the following strengths.

- The approximate boundary can be detected even in the presence of high level noise.
- Results show that the time taken to register a slice is less than a second.

In Fig. 1-5 the results of the proposed method has been presented.

Fig.1: An input source CT image sample

Fig. 2: A reference CT image

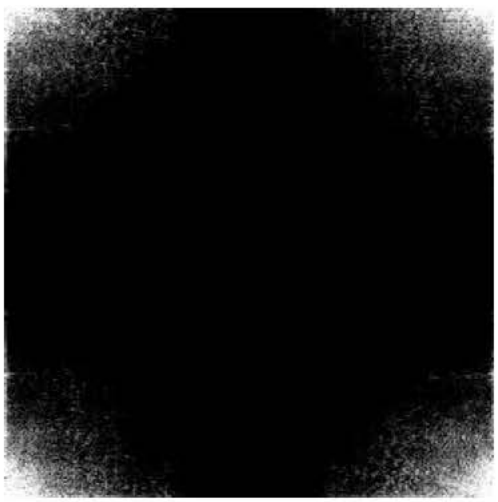

Fig. 3: Figure of correlated magnitude

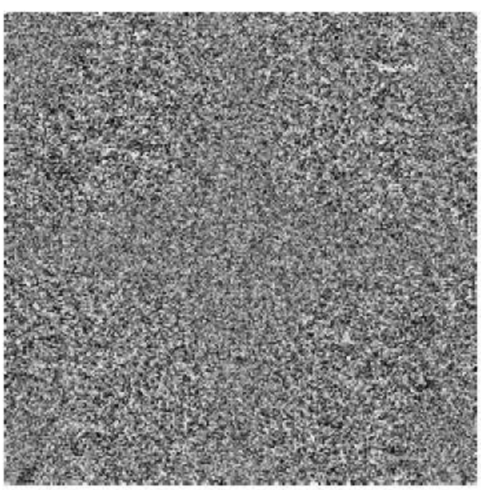

Fig. 4: Figure of correlated phase

Fig. 5: Accurately registered output image

CONCLUSIONS

It is found that the new fully automatic fast registration method for 2D CT images has the following strengths, namely,

- Fully automatic
- Less human interaction
- Significant reduction in computational speed
- Accurate image registration results
- The approximate boundary can be detected even in the presence of high level noise.
- Results show that the time taken to register a slice is less than a second. Hence a large number of slices can be registered within a few seconds.
- This algorithm guarantees computational speed in CT image registration, which is not guaranteed by many other algorithms.

These strengths of the new fully automatic fast registration method for 2D CT images makes the method very effective and accurate for accomplishing registration on 2D CT images.

The new proposed fully automatic fast registration method for 2D CT images therefore provides a desired alternate to conventional correlation methods. Future research by the authors will be focused to register multimodal images.

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